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**Data Multiplexing Network (DMN)
Phase IIIA Operational Test and
Evaluation (OT&E) Integration
and OT&E Operational Final
Test Report**

Ralph Riordan
Stephen Malitsky
Wayne E. Bell

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June 1994

DOT/FAA/CT-TN94/9

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| 16. Abstract This test report describes the results of the Operational Test and Evaluation (OT&E) Integration and OT&E Operational testing of the Statistical Time Division Multiplexer (STDM) Data Multiplexing Network (DMN) Phase IIIA commercial-off-the-shelf (COTS) equipment. Unit level tests were conducted at the Federal Aviation Administration (FAA) Technical Center and OT&E Integration and OT&E Operational tests were conducted at the Anchorage Air Route Traffic Control Center (ARTCC) and Minneapolis ARTCC. The equipment tested was the Type-I (DCX-808), Type-2 (DCX-832 and DCX-844), and the Type-III (DCX-850). The Cray STDM equipment was tested with the Codex 3600 modems. No problems were found during the unit level testing or OT&E Integration and OT&E Operational testing. The FAA Technical Center (ACW-400A) recommends deployment of the Cray Statistical Multiplexer equipment (Type I, Type II, and Type III). | | | |
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EXECUTIVE SUMMARY

This test report describes the results of the Operational Test and Evaluation (OT&E) Integration and OT&E Operational testing of the Statistical Time Division Multiplexer (STDM) Data Multiplexing Network (DMN) Phase IIIA commercial-off-the-shelf (COTS) equipment. Unit level tests were conducted at the Federal Aviation Administration (FAA) Technical Center and OT&E Integration and OT&E Operational tests were conducted at Anchorage, Alaska, and Minneapolis, Minnesota.

The DMN consists of a variety of transmission equipment used to consolidate and satisfy many National Airspace System (NAS) subsystem data communications requirements. The mission of the DMN Phase III program is to deploy cost-effective, reliable, and logistically supportable data communications networks that will support NAS requirements for the next 10 years. In April 1992, Dowty Communications, Inc. was awarded the prime contract for the DMN Phase IIIA STDM project. In September 1992, Dowty was acquired by Cray Electronics Holdings and the former Dowty is now known as Cray Communications. Cray Communications parent company, Cray Electronics Holdings, is an England-based communications company. The Cray statistical multiplexers are compatible with existing Paradyne DCX series equipment. This compatibility was verified during the Operational Capability Demonstration (OCD). Compatibility testing was not conducted at the FAA Technical Center or at the test site.

The FAA Technical Center received the statistical multiplexers in September 1992. The equipment tested during unit level testing was the Type-I (DCX-808), Type-II (DCX-832 and DCX-844), and the Type-III (DCX-850). Most of the unit tests were completed in December 1992. Tests that required two DCX-850s were completed in February 1993. During unit testing, the STDM equipment compiled a total of 3360 hours without a failure. No problems were uncovered during unit testing. The FAA Technical Center used a detailed Verification Requirements Traceability Matrix (VRTM) based on section-3 of the STDM specification (FAA-E-2860) as a basis for unit testing. The Cray STDM equipment was tested with the Codex 3600 modems.

The OT&E Integration and OT&E Operational testing was conducted at Anchorage for Flight Data Input/Output (FDIO) in May 1993. The OT&E Integration and OT&E Operational tests were also conducted at the Minneapolis Air Route Traffic Control Center (ARTCC) (ZMP) in June and in July 1993. ACW-400A also witnessed the installation and integration at ZMP. Many OT&E requirements were satisfied during this installation phase. No problems were found during unit level testing or OT&E Integration and OT&E Operational testing.

The FAA Technical Center (ACW-400A) recommends deployment of the Cray Statistical Multiplexer equipment (Type I, Type II, and Type III).

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1. INTRODUCTION.

This test report details the results of the Data Multiplexing Network (DMN) Phase IIIA Unit Level Testing and Operational Test and Evaluation (OT&E) Integration and OT&E Operational testing. All statistical multiplexers and ancillary equipment are commercial-off-the-shelf (COTS) equipment. Federal Aviation Administration (FAA) Specification FAA-E-2860 Data Multiplexer Network Statistical Multiplexers was used as the basis for unit level testing at the FAA Technical Center. This specification establishes the performance, design, test, manufacturer, and acceptance requirements for statistical multiplexers and ancillary equipment to be used for the DMN subsystem in the National Airspace System (NAS).

The specification details three distinct types of statistical multiplexers as follows:

- a. Type I Low capacity statistical multiplexers (up to 8 channels),
- b. Type II Medium capacity statistical multiplexers (up to 32 channels),
- c. Type III High capacity statistical multiplexer with network mapping, automatic rerouting, and supervisory control (up to 240 channels).

The statistical multiplexers will satisfy a growing FAA requirement for asynchronous data facilities. The statmux equipment will accept asynchronous data from multiple digital input ports and convert them into one or more digital synchronous composite links. The Type II (DCX-844) will accept four onward links from Type I (DCX-808) or Type II (DCX-832) equipment and combine them into one composite output.

The requirements in the specification were verified by either the FAA Technical Center unit tests or by the Technical Evaluation Team during technical evaluations, or during the operational capability demonstrations (OCD) conducted at Albuquerque in March and September 1990. In areas of the specification such as reliability, availability, altitude, compliance to FAA standards, electromagnetic interference, and susceptibility, etc., references are made to the Final Technical Evaluation Report. The Technical Evaluation Team has already evaluated the technical proposal and there is no reason to try to duplicate this work.

The detailed test procedures and data taken during the unit level testing are contained in the DMN Statistical Time Division Multiplexer (STDM) Unit Level Test Procedures document. The DMN STDM Unit Level Test Results document contains a completed Verification Requirements Traceability Matrix (VRTM) for the Type I, Type II, and Type III STDM equipment, containing the detailed results of the unit level tests conducted at the FAA Technical Center. A summary of the statistical multiplexer capabilities is displayed in table 1-1. Test procedures for OT&E testing are contained in the STDM-NAS OT&E Integration and OT&E Operational Test Procedures.

TABLE 1-1. SUMMARY OF DCX STATISTICAL MULTIPLEXER CAPABILITIES

| | <u>Type I</u> | <u>Type II</u> | <u>Type III</u> |
|----------------------------------|---------------|----------------|-----------------|
| Input Channels Maximum | 8 | 32 | 240 |
| Input Channel Data Rates Minimum | 50 bps | 50 bps | 50 bps |
| Maximum | 19,200 bps | 19,200 bps | 19,200 bps |
| Composite Links | 1 | 2 | up to 15 |

1.1 BACKGROUND.

The communications element of the NAS provides for voice and data exchange among the NAS functional areas and remote facilities to enable communications among users. Transmission equipment provides for the transmission of voice and data information among FAA subsystems and users. The mission of the statistical multiplexers is to provide continuous interfacility data connectivity for the NAS operations and access to public, private, or government systems external to the NAS.

In the late 1970's and early 1980's, the FAA established the requirement to reduce the number of dedicated leased point-to-point circuits. Data multiplexing technology offered the means to reduce the number of leased dedicated circuits between two points by multiplexing several data channels into a composite output and demultiplexing the output into discrete channels at the distant end. As a result, channel capacity was increased using the same number of existing dedicated circuits. The DMN Phase IIIA will expand the communications services available to the NAS by providing data communications equipment and services that exploit statistical time division multiplexing. A STDM, controlled by microprocessors, concentrates data by processing only channel activity, reformatting channel data into blocks, and transmitting the blocks when they are complete. Error-free transmission is assured by adding error control information to each block and by using an automatic retransmission upon receipt of error process known as Automatic Repeat Request (ARQ).

1.2 PURPOSE.

1.2.1 Purpose of STDM Unit Testing at the FAA Technical Center.

- a. Verify Requirements in STDM Specification FAA-E-2860
- b. Verify Requirements in NAS-SS-1000
- c. Familiarize FAA Personnel with STDM Equipment
- d. Gather Reliability Data
- e. Identify Problems
- f. Document Test Procedures and Configurations
- g. Preparation For OT&E Tests

1.2.2 Purpose of OT&E Integration and OT&E Operational Tests.

- a. Test NAS System End-to-End Performance
- b. Verify Operational Effectiveness and Suitability
- c. Identify Problems and Deficiencies

1.3 TEST PARTICIPANTS.

| | | |
|----------------|---------------------|------|
| Wayne Bell | ACW-400A | APMT |
| Ralph Riordan | ACW-400A | |
| Phil Hoang | ACW-400A | |
| Steve Malitsky | ACW-400A | |
| Daryl Hill | AMA-120 | |
| Dave Westfall | Cray Communications | |

(Installation)

| | |
|------------------|------------|
| Howard Atchley | ZAN-AFS |
| Dave Stefonowicz | ZMP-AFS |
| Bob Wolf | ZMP-MiTech |
| Gene Klem | ZMP-AFS |
| Gary Mathison | ZMP-AFS |
| Kent Hering | MIN GNAS |
| Tim Lyke | MIN GNAS |

1.4 REFERENCE DOCUMENTS.

- | | |
|---|----------|
| a. Specification. FAA-E-2860 Data Multiplexer Network Statistical Multiplexers | 07-20-89 |
| b. Data Multiplexing Network (DMN) Operational Capabilities Demonstration Statistical Time-division Multiplexers Test Report | 04-06-90 |
| c. Data Multiplexing Network Phase III Equipment, Master Test Plan | 10-29-90 |
| d. STDM Final Technical Evaluation Report | 12-20-90 |
| e. DMN Statistical Multiplexer Unit Level Testing Requirements | 09-11-92 |
| f. DMN Statistical Multiplexer Unit Level Test Procedures Document | 02-26-93 |
| g. DMN Statistical Multiplexer Unit Level Testing Results Document | 03-19-93 |

h. STDM-NAS OT&E Integration and OT&E
Operational Test Procedures

04-30-93

i. NAS-SS-1000, Volume I, General

j. NAS-SS-1000, Volume IV, Communications Element

2. TEST APPROACH AND CONCEPT.

Unit level testing and OT&E testing for the statistical multiplexer program was designed to take advantage of prior testing, whenever possible, in order to avoid duplication of tests. Similar equipment is operational in the field. The Cray Communications equipment will update existing equipment and add additional capabilities. No formal factory testing was performed for the statistical multiplexers. However, Cray Communications does subsystem and system tests prior to shipment of the equipment. Unit level testing attempted to verify as many requirements as possible from the specification (FAA-E-2860). Some requirements such as environmental tests could not be performed at the FAA Technical Center. These requirements were evaluated by the Technical Evaluation Team when they evaluated the proposal.

ACW-400A witnessed the installation and cutover activities at Minneapolis Air Route Traffic Control Center (ARTCC) (ZMP). The OT&E testing considered tests that had been previously conducted, including testing performed during installation, to minimize the amount of time required to perform OT&E tests.

The testing program for the DMN statistical multiplexers consisted of:

- a. OCD at Albuquerque ARTCC (ZAB) 1990
- b. Unit level tests at FAA Technical Center
- c. Installation/cutover at ZMP and remotes
- d. CT&E tests at Anchorage ARTCC (ZAN) and ZMP
- e. Shakedown tests at ZMP

The requirements in the DMN Statistical Multiplexer Specification (FAA-E-2860) were verified by one of the following methods:

- a. FAA Technical Center Unit Testing
- b. Reference To Technical Evaluation Final Report
- c. OCD Conducted At Albuquerque ARTCC
- d. OT&E Integration and OT&E Operational Tests
- e. Shakedown Tests

3. TEST RESULTS.

3.1 TECHNICAL EVALUATIONS.

The Final Technical Evaluation Report for the DMN Phase IIIA STDM equipment was issued December 20, 1990. The FAA Technical Center unit level tests did not attempt to duplicate this effort. Several requirements were referenced to the Final Technical Evaluation Report in an effort to save time and money. Some of the requirements in the statistical multiplexer specification could not be verified at the FAA Technical Center because they would require special equipment or facilities.

The following requirements were verified by reference to the Technical Evaluation Final Report

- a. T-Pause Option To Support Operation Of Tandem Equipment
- b. Electromagnetic Interference and Susceptibility
- c. Compliance to FCC regulations
- d. Compliance to FAA standards
- e. Interchangeability
- f. Maintainability
- g. Availability
- h. Grounding
- i. Reliability
- j. Altitude

3.2 OPERATIONAL CAPABILITY DEMONSTRATIONS.

The OCDs were conducted at the ZAB in March and September 1990. The OCD was established as part of the technical evaluation process prior to contract award. The OCD verified the ability of the proposed equipment to meet critical requirements of the DMN statistical multiplexer specification. The primary purpose of the OCD tests was to demonstrate the compatibility with existing American Telephone and Telegraph (AT&T) Paradyne statistical multiplexer equipment currently used by the FAA.

The following requirements were verified during the OCD:

- a. Compatibility With Existing STDMs
- b. Onward Link Capability
- c. Automatic Rerouting
- d. Port Contention
- e. Noninterfering Reconfiguration
- f. Type III Diagnostic Capability
- g. Type III Monitoring

3.3 FAA TECHNICAL CENTER UNIT LEVEL TESTS.

The intent of unit level testing at the FAA Technical Center was to verify as many requirements as possible from FAA specification FAA-E-2860 (section-3) within the limitations of time and equipment. The DMN Statistical Multiplexer Unit Level Testing Requirements document was used as a guide for testing. The Unit Level Requirements document is a detailed VRTM derived from the specification. The unit level tests were performed from September 14, 1992, through February 8, 1993, at the FAA Technical Center. Tests conducted during OCDs were not duplicated in all cases during unit testing. Some requirements are not practical to test except in a factory environment, and may require special test equipment or facilities.

The STDM equipment performed well during unit testing and there were no equipment failures. Detailed test results for FAA Technical Center unit level tests are contained in the STDM Unit Level Test Results document. Detailed test procedures, test equipment, and test data are contained in the STDM Unit Level Procedures document. The Cray STDM equipment was tested with the Codex 3600 modems.

FAA Technical Center Unit Level Tests included the following tests:

- a. General Characteristics Type I, II, and III
- b. Type I Statistical Multiplexer Requirements
- c. Type II Statistical Multiplexer Requirements
- d. Type III Statistical Multiplexer Requirements
- e. Ancillary Equipment
- f. Physical Characteristics

Equipment tested during FAA Technical Center Unit Level Tests:

- a. Cray DCX-808
- b. Cray DCX-832
- c. Cray DCX-844
- d. Cray DCX-850

3.3.1 Unit Level Block Diagrams.

The unit level block diagrams (figures 3.3.1-1 through 3.3.1-7) show the various unit level test configurations in which the the STDM equipment was tested at the FAA Technical Center. The unit level test configurations are:

- a. STDM basic test configuration
- b. Split baud rate test configuration
- c. Switching and control test configuration
- d. Error detection and retransmission tests
- e. DCX-808 and DCX-832 56 kbps composite link test configuration
- f. X.25 test configuration
- g. Remote configuration and load balancing test configuration

Unit Level Tests

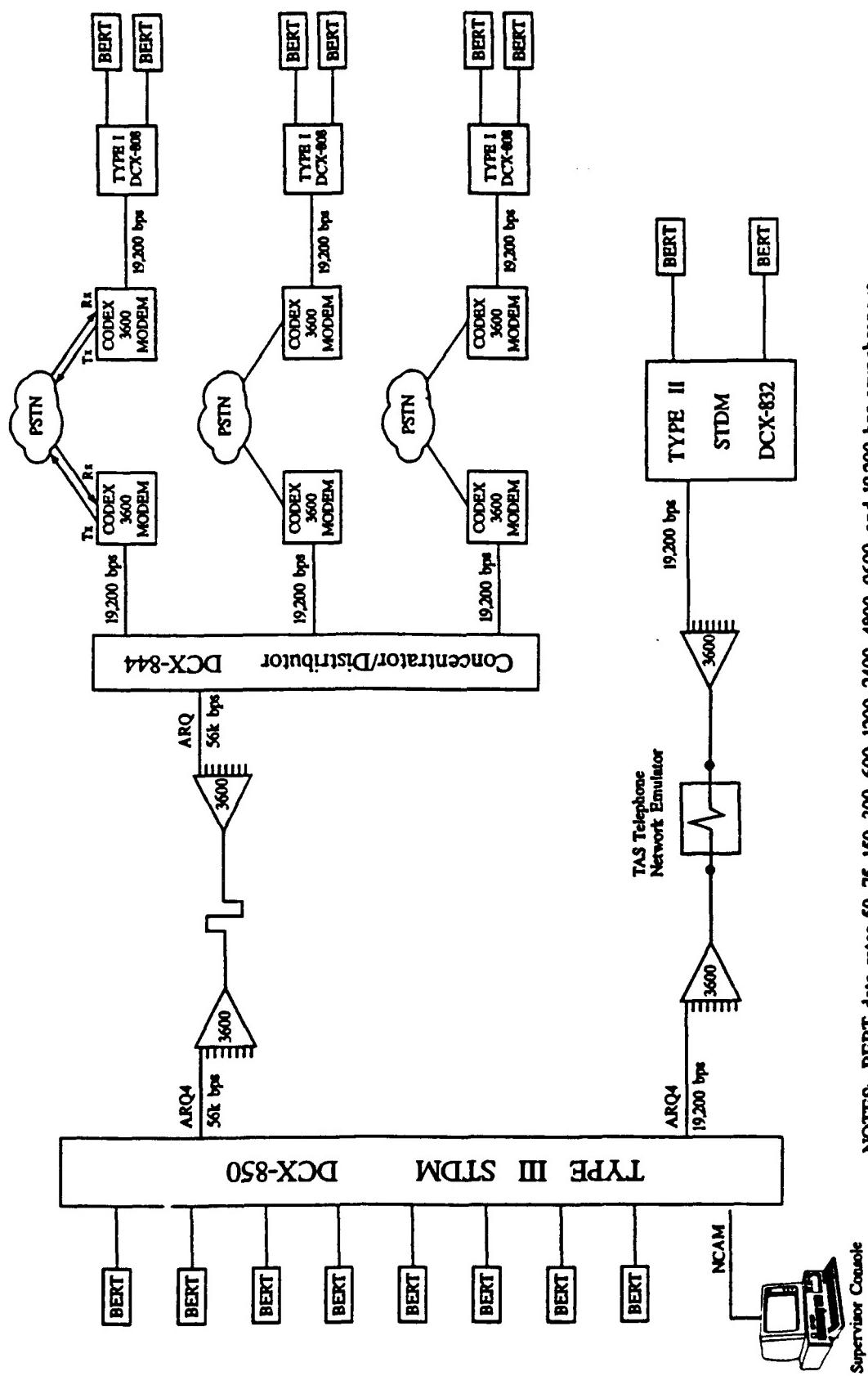


FIGURE 3.3.1-1. STDM BASIC TEST CONFIGURATION

Unit Level Tests

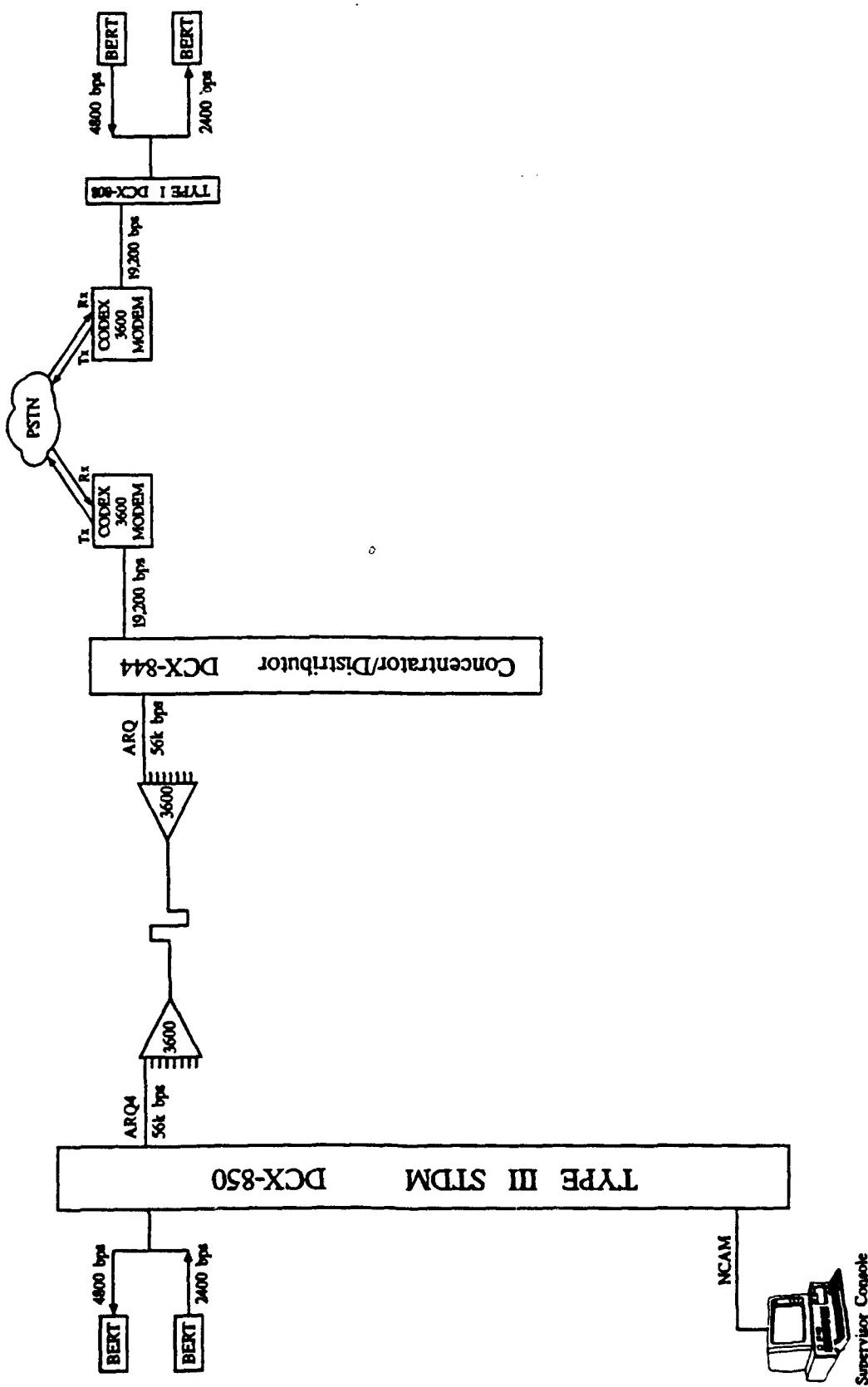


FIGURE 3.3.1 - SPLIT BAUD RATE TEST CONFIGURATION

Unit Level Tests

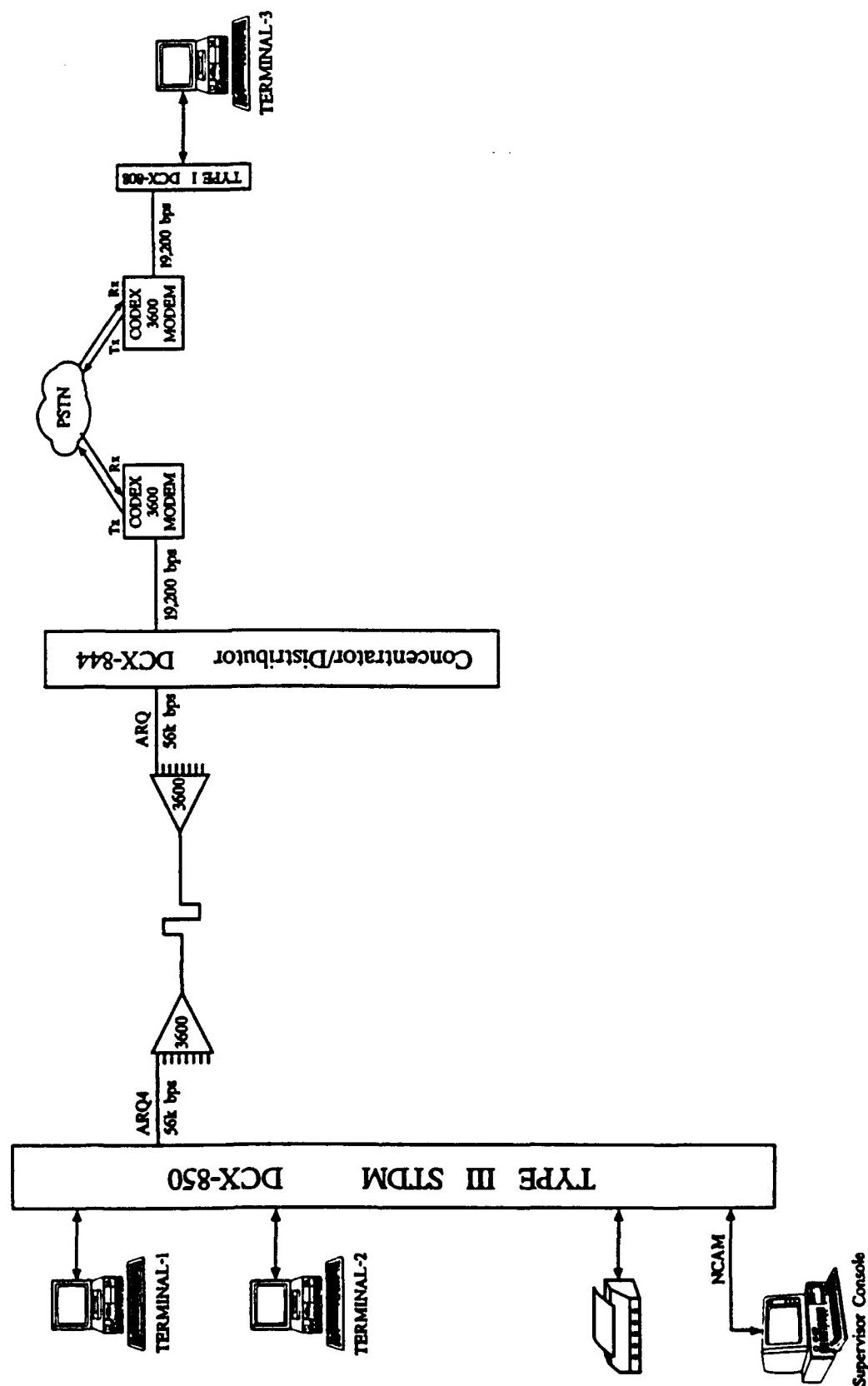


FIGURE 3.3.1-3. SWITCHING AND CONTROL TEST CONFIGURATION

Unit Level Tests

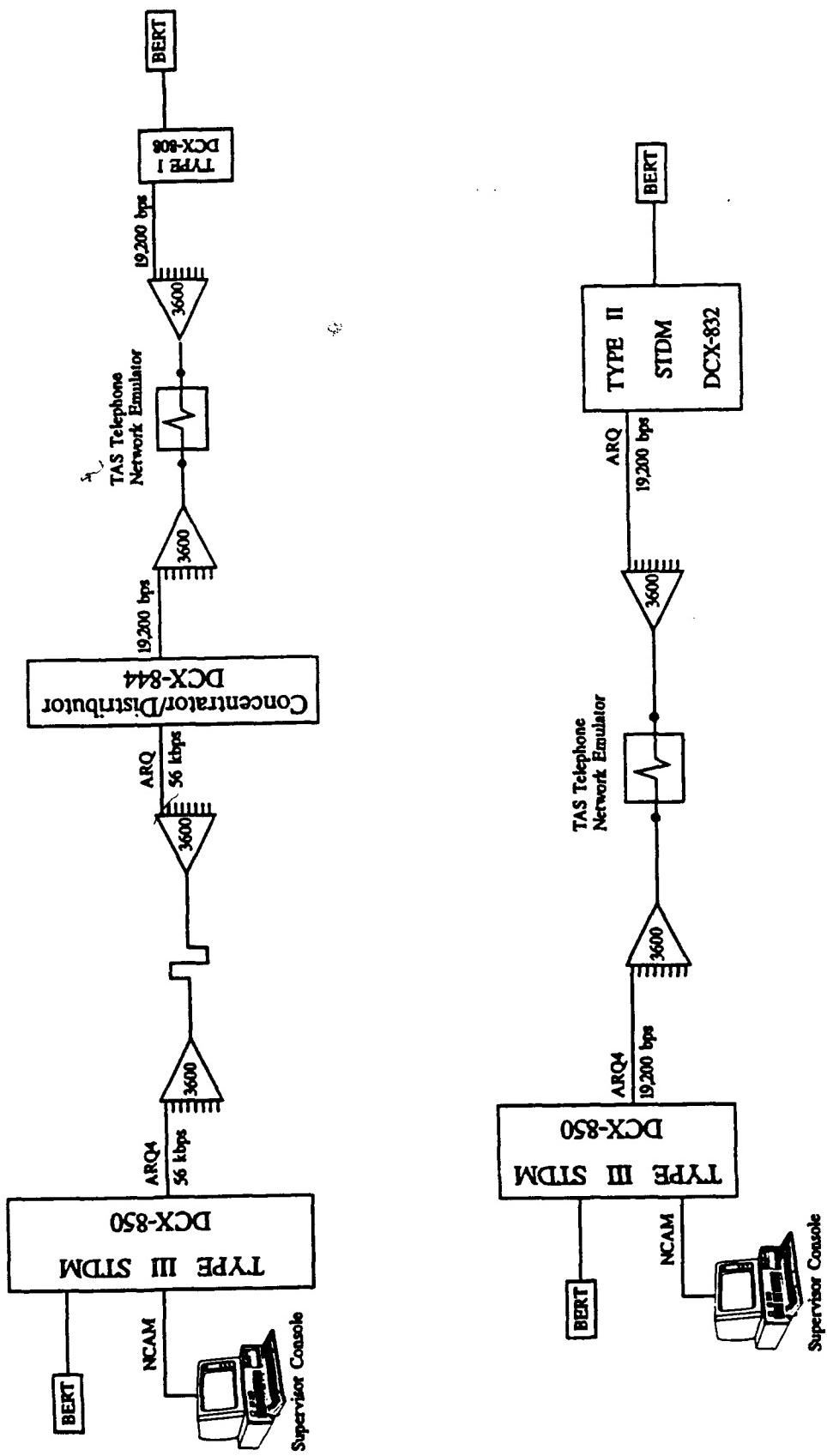
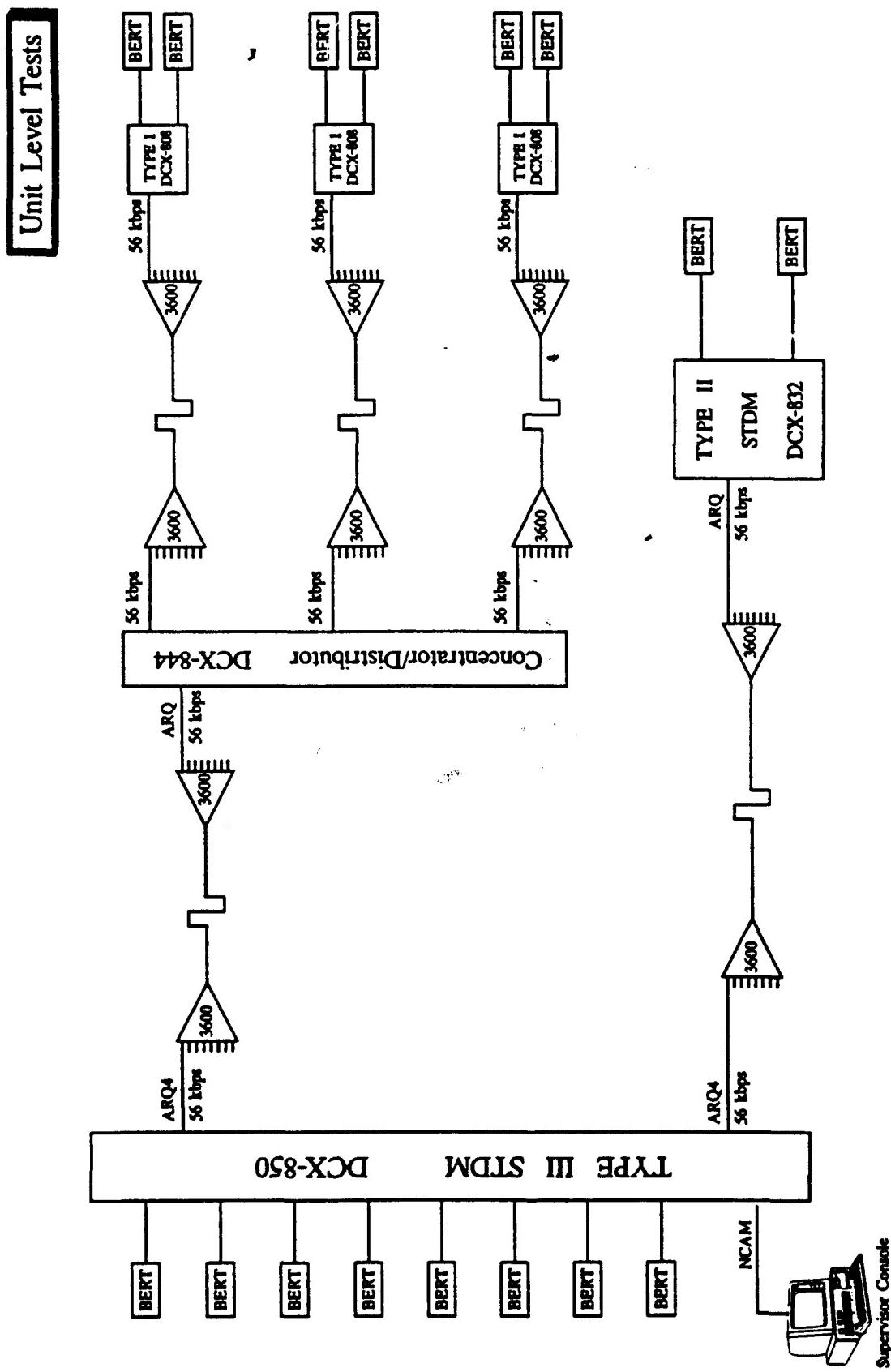


FIGURE 3.3.1-4. ERROR DETECTION AND RETRANSMISSION TESTS



NOTES: BERT Data Rate 19200 bps asynchronous

FIGURE 3.3.1-5. DCX-808 AND DCX-832 COMPOSITE LINK TEST CONFIGURATION

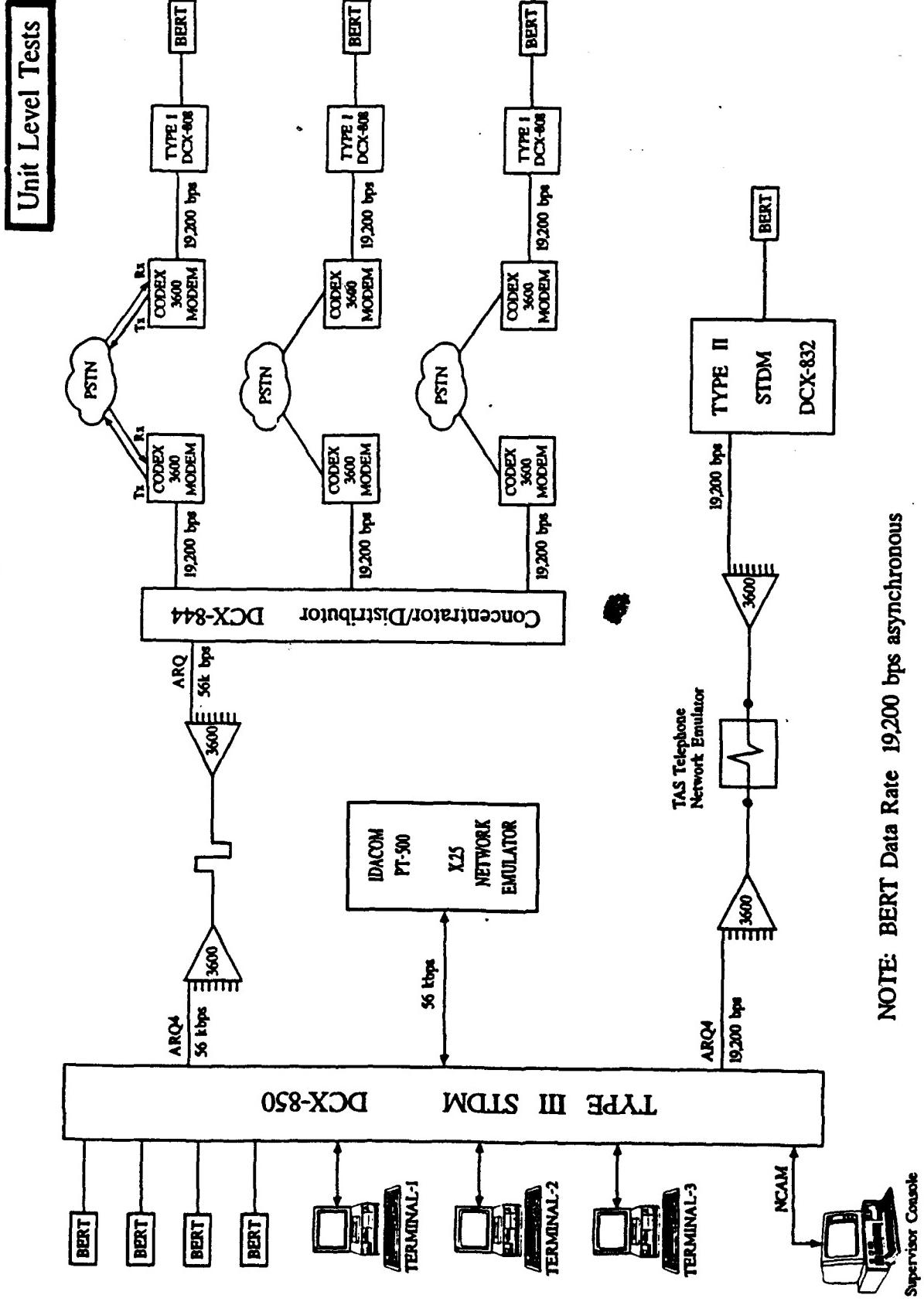


FIGURE 3.3.1-6. X.25 TEST CONFIGURATION

Unit Level Tests

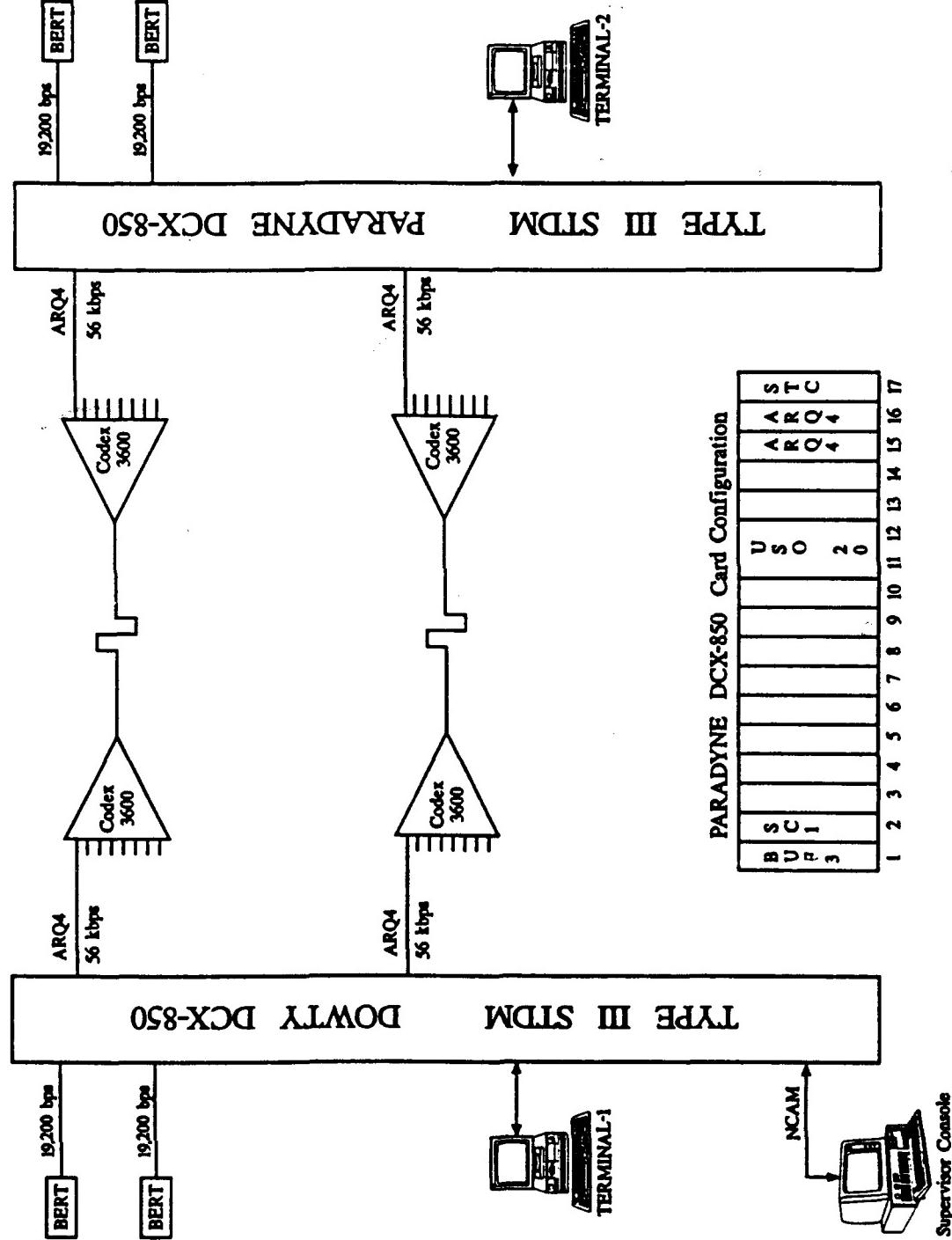


FIGURE 3.3.1-7. REMOTE RECONFIGURATION AND LOAD BALANCING

3.3.2 Requirements Verified During Unit Level Tests.

Unit level testing verified many requirements from FAA-E-2860 and NAS-SS-1000. Protocol compatibility was not verified at the FAA Technical Center but was verified during the OCD. Automatic rerouting was not verified at the FAA Technical Center, but was also previously verified during the OCD. The following requirements were verified during FAA Technical Center unit level tests:

a. GENERAL CHARACTERISTICS FOR TYPE I, II, and III

1. Performance Characteristics
2. Digital Interfaces
3. Interface Options
4. Input Channel Specifications
5. Composite Link Specifications
6. Other Specifications
7. Controls
8. Status Indicators

b. TYPE I STATISTICAL MULTIPLEXER REQUIREMENTS

1. Input Channel Specifications
2. Composite Link Specifications

c. TYPE II STATISTICAL MULTIPLEXER REQUIREMENTS

1. Input Channel Specifications
2. Composite Link Specifications

d. TYPE III STATISTICAL MULTIPLEXER REQUIREMENTS

1. Input Channel Specifications
2. Composite Link Specifications
3. Other Specifications
4. Controls
5. Status Indicators
6. Monitor
7. Packet Switch Interface
8. Switching and Control
9. Diagnostics

3.4 INSTALLATION AND CUTOVER AT ZMP ARTCC AND REMOTES.

Installation and cutover was conducted at ZMP and 13 remote sites from June 14 through June 18, 1993. Installation was completed at a 14th remote site, Minneapolis/St. Paul Air Traffic Control Tower (MSP ATCT), approximately June 28, 1993. The configuration at ZMP consisted of three DCX-840s and two DCX-850s. The installation and cutover activities were directed by AMA-120 with assistance from Cray Communications and ZMP personnel. Many ST&E requirements were satisfied during the installation/cutover phase. ACW-400A personnel observed the installation/cutover activities which are considered part of the overall testing program. Appendix B gives a list of remote sites and equipment installed, tested, and cutover.

The following requirements were verified during installation/cutover:

- a. Apollo
- b. CBI-Viking
- c. CBI-PC
- d. MMS-Terminal
- e. MMS-Printer

The following equipment was installed and cutover:

- a. DCX-808
- b. DCX-816
- c. DCX-832
- d. DCX-840
- e. DCX-844
- f. DCX-850

3.5 OT&E INTEGRATION AND OT&E OPERATIONAL TESTS.

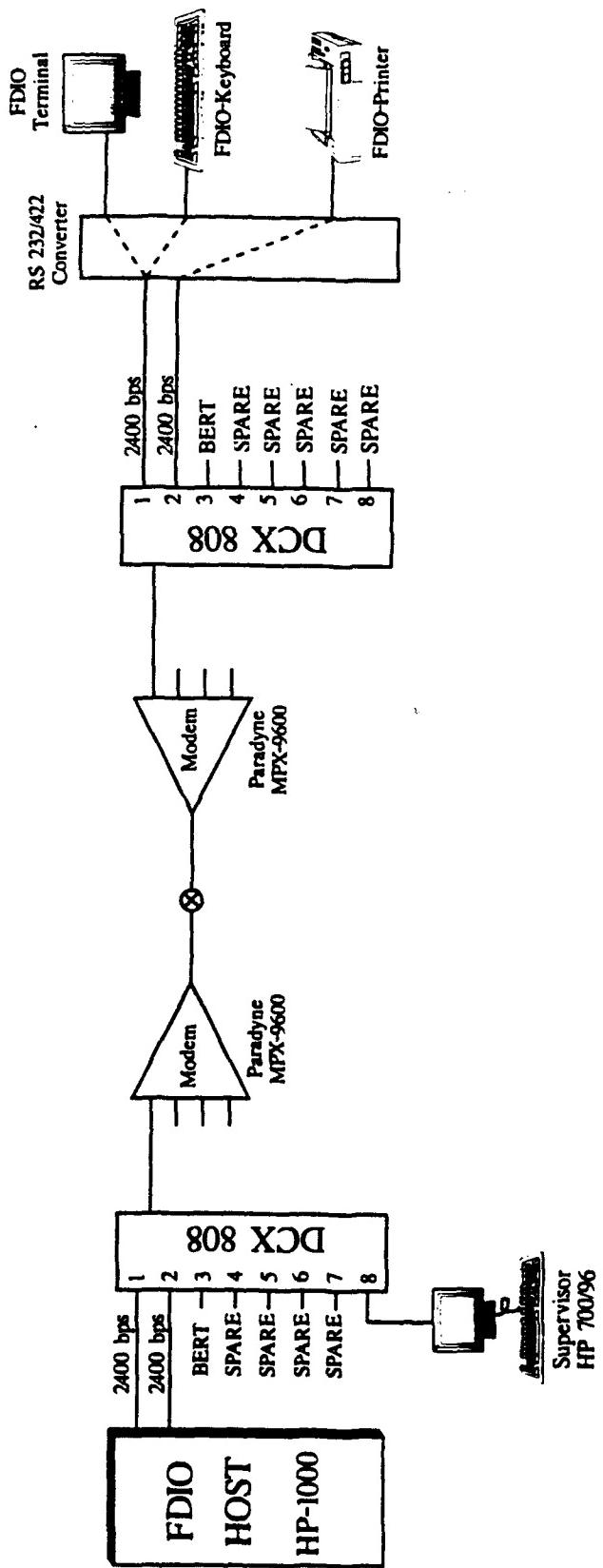
The objectives of OT&E Integration and OT&E Operational testing is to evaluate the suitability and effectiveness of Types I, II, and III statistical time-division multiplexers and their ability to interface with existing NAS subsystems. The OT&E Integration and OT&E Operational tests for Flight Data Input/Output (FDIO) were conducted at Anchorage (figure 3.5-1). The Minneapolis ARTCC (ZMP) was the focal point for OT&E Integration and OT&E Operational tests for Computer Based Instruction (CBI) and Maintenance Monitoring System (MMS) (figures 3.5-2 and 3.5-3). The OT&E requirements for Apollo were satisfied during the installation/cutover (figure 3.5-4). The test procedures used for OT&E Integration and OT&E Operational testing are detailed in the STDM-NAS OT&E Integration and OT&E Operational Test Procedures document.

The following tests are specified in the STDM-NAS OT&E Integration and OT&E Operational Test Procedures:

- a. DCX-DCX On-Line Interface Test for CBI,
- b. CBI On-Line Interface Test,
- c. CBI Operational Readiness Demonstration,
- d. DCX-DCX On-Line Interface Test for MMS,
- e. MMS On-Line Interface Test,
- f. MMS Operational Readiness Demonstration,
- g. DCX-DCX On-Line Interface Test for Apollo,
- h. Apollo On-Line Interface Test,
- i. Apollo Operational Readiness Demonstration,
- j. DCX-DCX On-Line Interface Test for FDIO,
- k. FDIO On-Line Interface Test,
- l. FDIO Operational Readiness Demonstration.

ZAN
ARTCC

ANC
ATCT (Simulated)



Notes:

BERT-Bit Error Rate Tester (2400 bps)

FIGURE 3.5-1. ANCHORAGE FDIO OT&E TEST CONFIGURATION

ZMP
ARTCC

MIN
GNAS

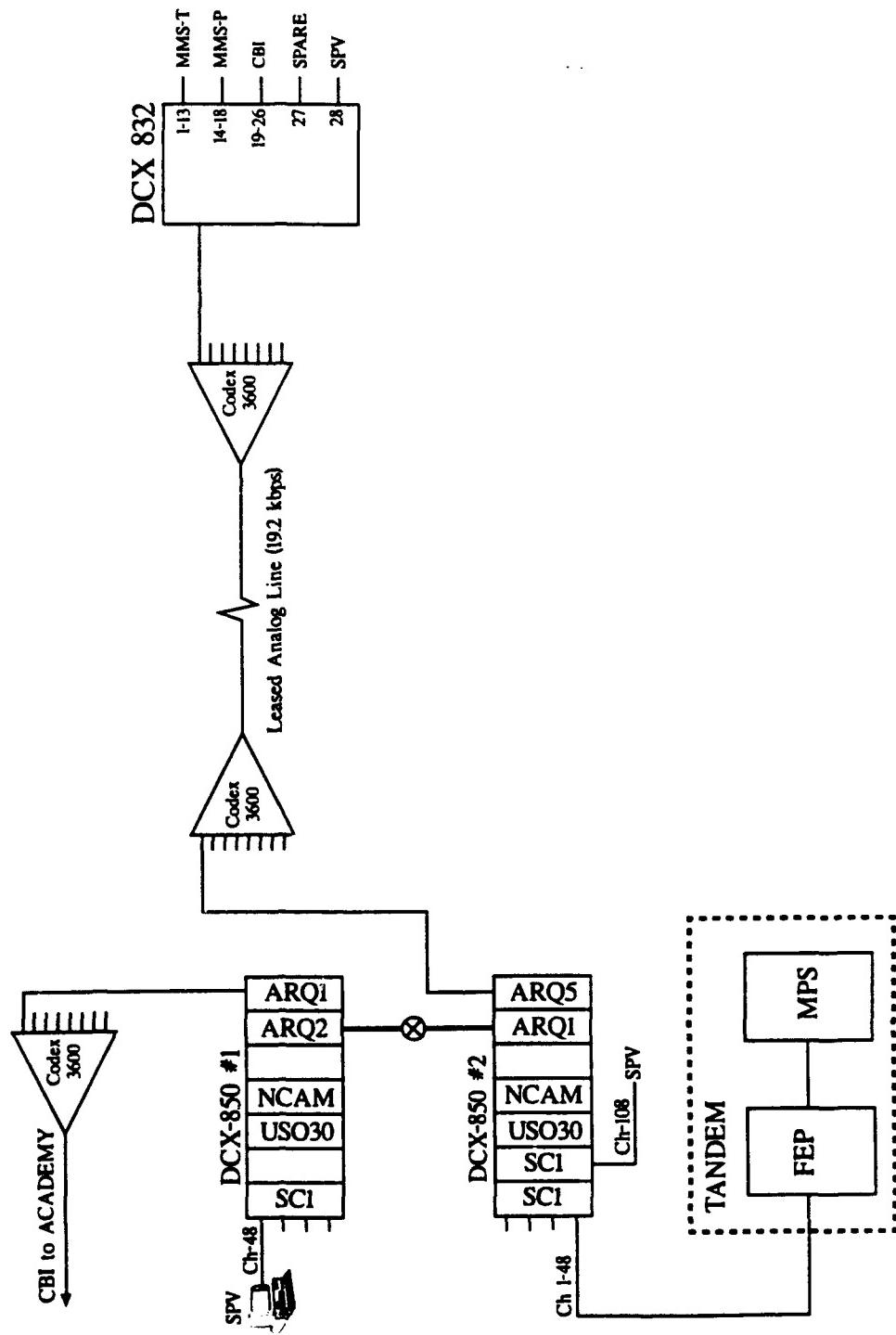


FIGURE 3.5-2. OT&E TEST CONFIGURATION CBI AND MMS TEST (MIN GNAS)

ZMP
ARTCC

MSP
ATCT

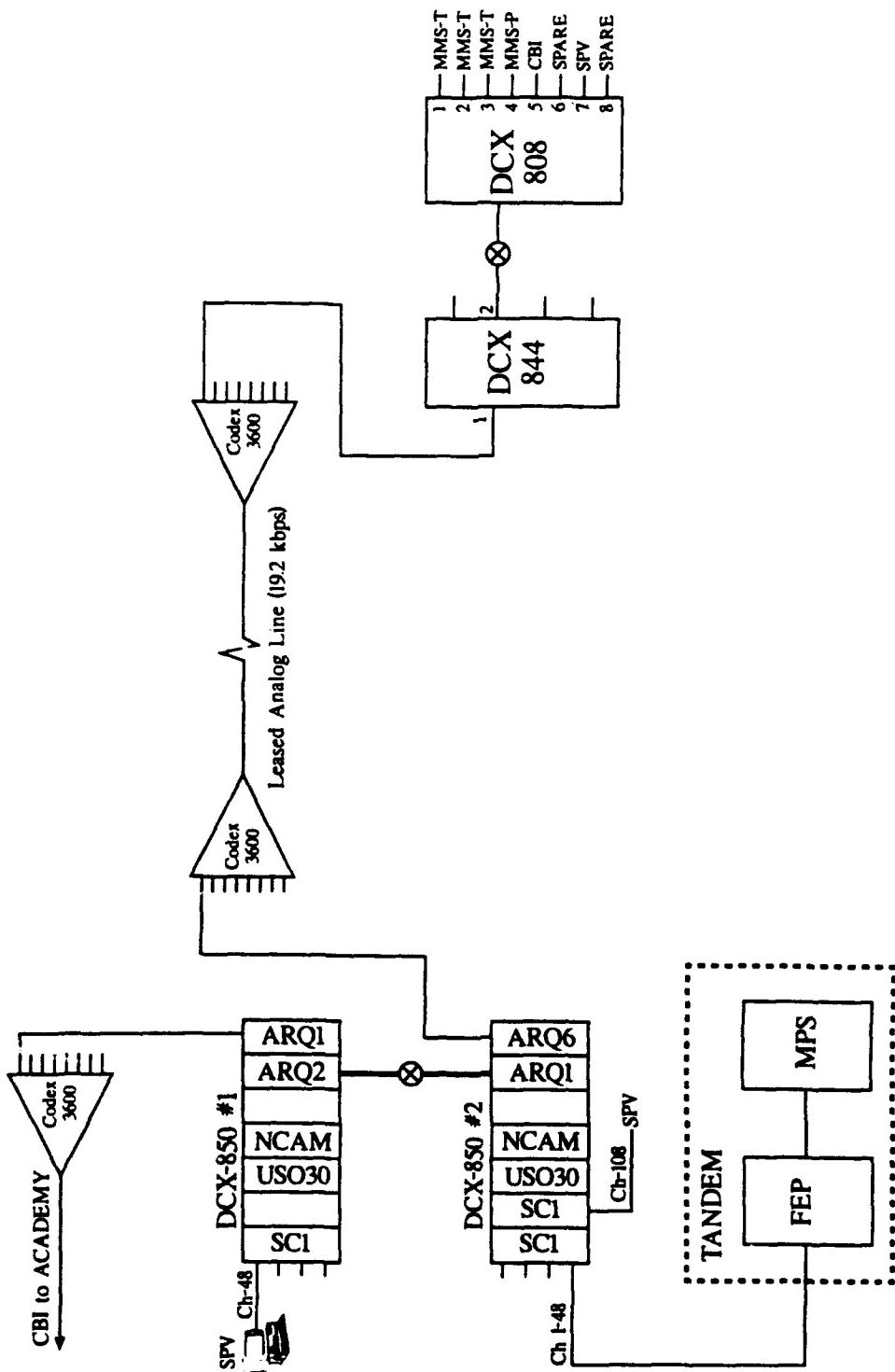


FIGURE 3.5-3. OT&E TEST CONFIGURATION CBI AND MMS TESTS (MSP ATCT)

ZMP

ARTCC

ZCX

FAA Technical Center

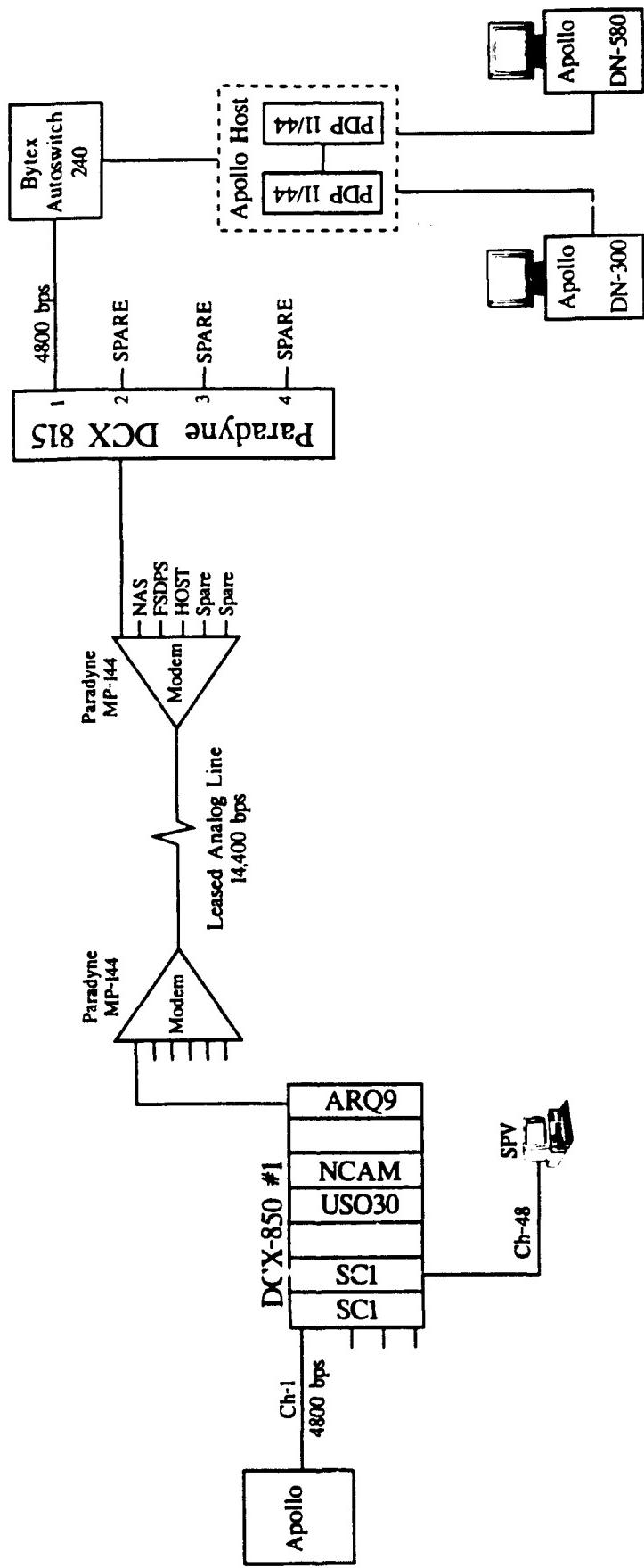


FIGURE 3.5-4. APOLLO TEST CONFIGURATION (INSTALLATION/CUTOVER)

3.5.1 OT&E Integration And OT&E Operational Tests (Apollo).

The OT&E requirements for Apollo were satisfied during the installation/cutover. The installation and cutover tests (figure 3.5-4) were similar to the on-line interface test contained in the STDM-NAS OT&E Integration and OT&E Operational Test Procedures. After cutover, proper operation of the Apollo system was verified with the air traffic controllers at ZMP. The day after cutover, a monitor card in the statmux at ZMP was configured to monitor the Apollo data. The data was normal. Proper operation of the system was also verified at the FAA Technical Center Traffic Management System (TMS) (ZCX). No problems were reported by the users. Additional OT&E testing for the Apollo system was not required.

The requirement for the 24-hour operational readiness demonstration was satisfied since Apollo cutover occurred on June 17, 1993, and monitoring at ZMP occurred 24 hours later. In addition, verification at the FAA Technical Center was accomplished several times, up to 3 weeks after cutover.

3.5.2 OT&E Integration And OT&E Operational Tests (FDIO).

The FDIO OT&E Integration and OT&E Operational tests were performed at Anchorage from May 25 through 27, 1993 (figure 3.5-1). The test procedures used were similar to those detailed in the STDM-NAS OT&E Integration and OT&E Operational Test Procedures. The FDIO configuration at Anchorage (figure 3.5-1) is unique. The ZAN ATCT configuration was simulated from the ZAN. The FDIO terminal, FDIO printer, FDIO keyboard, and FDIO host computer (HP-1000) were exercised during the test. A bit-error rate test was also run simultaneously. The data ran error-free. Flow control was used on the bit-error rate tester and the FDIO printer. The FDIO host computer (HP-1000) generated test messages to the terminal and printer. The data sent to the terminal included both test messages and operational messages.

No problems were found during OT&E Integration and OT&E Operational testing at Anchorage. The DCX-808 configuration was also verified during the tests. The requirement for the 24-hour operational readiness demonstration was satisfied by running the equipment overnight. In addition, the DCX-808s were loaned to Anchorage so that field personnel could familiarize themselves with the equipment, and run any additional tests they felt were necessary.

3.5.3 OT&E Integration And OT&E Operational Tests (CBI).

The CBI testing was conducted by AMA-120 during installation/cutover June 16 and 17, 1993. Appendix B gives a list of the remote sites and CBI equipment tested during the installation.

The CBI OT&E Integration and OT&E Operational tests (figures 10 and 11) were conducted from the MIN GNAS on June 18 and July 21, 1993. Both the CBI-Viking platform and the CBI-PC platform were exercised during the MIN GNAS tests. The CBI OT&E tests were also conducted from the MSP ATCT on July 21, 1993. The CBI-Viking platform was tested from the MSP ATCT.

All CBI tests were successful. No problems were found during the CBI OT&E Integration and OT&E Operational tests. During the OT&E tests, the CBI terminal was operated by the users. The requirement for the 24-hour operational readiness demonstration was satisfied since CBI tests were conducted during installation/cutover June 16 and 17, 1993, as well as OT&E tests of June 18 and July 21, 1993.

3.5.4 OT&E Integration And OT&E Operational Tests (MMS).

The MMS testing (figures 3.5-2 andd 3.5-3) was conducted by AMA-120 during installation/cutover on June 16 and 17, 1993. Appendix B gives a list of the remote sites and MMS equipment tested during the installation.

The OT&E Integration and OT&E Operational tests for MMS were conducted from ZMP to the Minnesota (MIN) General National Airspace System (GNAS) on June 18 and again on July 21, 1993. These tests consisted of the MMS on-line interface tests described in the STDM-NAS OT&E Integration and OT&E Operational Test Procedures. The MMS terminal and MMS printer were exercised during these tests. During OT&E tests, the MMS terminal and printer were operated by the users. The requirement for the 24-hour operational readiness demonstration was satisfied since MMS tests were conducted during installation/cutover June 16 and 17, 1993, as well as OT&E tests, June 18 and July 21, 1993.

The MMS software at ZMP was updated to a new release (Software Release A04/R08 MMS IMCS) the week of July 12, 1993. Additional MMS OT&E tests were conducted July 21, 1993, from the MIN GNAS and the MSP ATCT. The MMS terminal and printer were exercised from the MIN GNAS. Two MMS terminals and one MMS printer were tested from the MSP ATCT on July 21, 1993.

3.6 SHAKEDOWN TESTING (AOS-240).

Shakedown testing was conducted at the Minneapolis ARTCC from July 26 to August 3, 1993, by AOS-240. The goal of Shakedown testing is to verify operational suitability of the DMN Phase IIIA STDM equipment in the areas of service, training, logistics, documentation, personnel safety, security, catastrophic failures, degraded operations, preventive maintenance, site peculiar/adaptation data, operability, second-level support, and field maintainability. The Shakedown test team has designated as critical those exceptions which require correction prior to deployment. Essential exceptions are problems which also require immediate attention, but these problems would not be aggravated by or hamper further system development.

Refer to the Shakedown Test Procedures, dated March 17, 1993, and the Final Report, Shakedown Test Results, dated August 16, 1993, for details of the tests performed and the results of these tests.

3.7 REQUIREMENTS NOT VERIFIED.

The requirements for Split Bandwidth (3.1.1.4.5.3) and Protocol Conversion (3.1.1.4.5.5) were not tested during FAA Technical Center unit tests since they require additional modules not supplied to the FAA Technical Center. There are no near-term requirements for split bandwidth or protocol conversion. These items will be tested, if required, to meet future requirements. The specification requires that all text shall also be provided on 5 1/4" MS DOS compatible disk media. The FAA Technical Center was not supplied text on 5 1/4" media. This requirement was not tested. Text in electronic form is available from the contractor, if required.

3.8 REQUIREMENTS EXCEEDED.

The Cray DCX STDM equipment exceeded specifications in several key areas.

The Type I can support a composite link speed of 56 kilobits per second (kbps). The specification requires only 19,200 bits per second (bps) composite link speed for Type I equipment.

The Type II specification requires a composite link speed of 19,200 bps. The DCX-816/832 can support a composite link speed up to 76.8 kbps. The maximum composite link rate for the DCX-844 is 80 kbps. The DCX-816/832 has two composite links. The specification requires only one composite link. The specification requires the Type II equipment to accept three onward links. The DCX-844 can accept four onward links.

The Type III specification requires a composite link speed of up to 56/64 kbps. The DCX-840/850 has a maximum composite link speed of 80 kbps.

The buffer sizes probably exceed the specifications, however, information on buffer sizes was not included with the documentation supplied to the FAA Technical Center. The Type I and Type II composite link was tested at 19.2 kbps and 56 kbps during unit level testing at the FAA Technical Center.

3.9 SYSTEM THROUGHPUT.

FAA-E-2860 requires that input channel data rates include data rates up to 19,200 bps. However, system throughput and delay are not specified.

During unit testing, it was observed that the throughput was limited to about 9,600 bps on a single channel (flow control was used). Additional information was requested and supplied by the contractor (appendix A). This information indicates that a SC-1 module on the DCX-840/850 is limited to a bandwidth of 9,900 bps maximum for the whole module. The module has four asynchronous channels and each channel can support data rates to 19,200 bps. Therefore, the throughput of the SC-1 module on the DCX-840/850 system is about one-eighth of the total maximum input channel data rate. The DCX-808 and DCX-816/832 throughput is 8970 bps at 9600 bps. The throughput is 9265 bps at 19,200 bps.

Users of the STDM equipment do not send continuous data. Therefore, system throughput at high input data rates is not a problem. Also, the STDM equipment has flow control capability and buffers to limit data flow or store data when required.

4. NAS REQUIREMENTS.

Appendix-B gives NAS-SS-1000, Volume I and NAS-SS-1000, Volume IV requirements that are applicable to this COTS STDM equipment. The Cray STDM equipment was not designed to support remote maintenance capabilities. Therefore, those NAS requirements pertinent to remote monitoring capability cannot be supported by the Cray STDM equipment. There are no applicable NAS SS-1000, Volume I requirements for Type I or Type II equipment.

The Cray STDM equipment exceeds the NAS requirement for input data rates. The NAS SS-1000 requirement for input data rates is from 50 to 9600 bps. The Cray STDM equipment can support input data rates from 50 to 19,200 bps.

5. CONCLUSIONS.

The overall testing program for the Cray Statistical Time Division Multiplexer (STDM) equipment consisted of (1) operational capability demonstrations, (2) unit level tests at the Federal Aviation Administration (FAA) Technical Center, (3) installation/cutover at Minneapolis Air Route Traffic Control Center (ARTCC) (ZMP) and remotes, (4) Operational Test and Evaluation (OT&E) Integration and OT&E Operational tests, and, (5) OT&E Shakedown tests.

The results of these tests indicate that the Cray STDM equipment is reliable, suitable, and effective. The Cray STDM equipment performed flawlessly during FAA Technical Center unit level tests and OT&E tests. All requirements that were tested passed. No equipment failures occurred and data was transferred error-free across the link. The equipment reliability was 100 percent during unit level tests and OT&E tests. The equipment was operated in a temperature controlled environment. The DCX-850 was stressed more than normal at the FAA Technical Center since it was operated without fans under each chassis.

The STDM testing verified that the Cray STDM can transfer data reliably and can be configured for a variety of applications.

6. CONCERNS/ISSUES.

There are no concerns or issues that resulted from unit level testing or OT&E Integration and OT&E Operational testing.

7. RECOMMENDATION.

The FAA Technical Center recommends deployment of the following equipment:

- a. Cray DCX-808 STDM
- b. Cray DCX-816 STDM
- c. Cray DCX-832 STDM
- d. Cray DCX-840 STDM
- e. Cray DCX-850 STDM
- f. Cray DCX-844 Concentrator/Distributor

8. ACRONYMS.

| | |
|-------|--|
| AFSFO | Airway Facilities Sector Field Office |
| ARQ | Automatic Repeat Request |
| ARSR | Air Route Surveillance Radar |
| ARTCC | Air Route Traffic Control Center |
| ATCT | Air Traffic Control Tower |
| bps | bits per second |
| CBI | Computer Based Instruction |
| COTS | Commercial-Off-The Shelf |
| DCX | Data Concentration Ex change |
| DMN | Data Multiplexing Network |
| FAA | Federal Aviation Administration |
| FDIO | Flight Data Input/Output |
| FEP | Front End Processor |
| GNAS | General National Airspace System (sector office) |
| kbps | kilobits per second |
| LSC | Low Speed Channel |
| MMS | Maintenance Monitoring System |
| MSP | Minneapolis/St. Paul, Minnesota Airport |
| MPS | Maintenance Processor Subsystem |
| NAS | National Airspace System |
| OCD | Operational Capability Demonstration |
| OT&E | Operational Test and Evaluation |
| SAIC | Science Applications International Corporation |
| SC | Soft Channel |
| SPV | Supervisory Channel |
| STDIM | Statistical Time-division Multiplexer |
| VRTM | Verification Requirements Traceability Matrix |
| ZAB | Albuquerque ARTCC |
| ZAN | Anchorage ARTCC |
| ZCX | FAA Technical Center Traffic Management System |
| ZMP | Minneapolis ARTCC |

APPENDIX A

CRAY COMMUNICATIONS PRODUCT SUPPORT MEMO

CRAY COMMUNICATIONS PRODUCT SUPPORT MEMO

Title: **THROUGH PUT INFORMATION ON CRAY EQUIPMENT**

From: David Westfall

Date: November 24, 1992

DCX 840 and DCX 850 PRODUCTS

The following information describe the framework for transferring data through the DCX 840 or DCX 850. The DCX MUX is designed around a BUS architecture. The BUS is clocked at 10Mhz, providing 16 microsecond cycles, each of which are sub divided into four data transfer slots which are shared evenly between High and Low Speed Devices. High Speed Devices are ARQs, Gates, Links, USOs, STC, etc. Low Speed Devices are the LSCs or SC1s.

High Speed devices contend for their slots. Low Speed devices are polled by the Master Buffer on a cyclic basis.

Data and Control transfer is simplex; it is either from the device to the buffer, or from the buffer to the device. Each transfer is a 12 bit "word" formed from an 8 bit plus additional internal Flags indicating whether it is data or control.

All LSCs or SC1s cards, which are the equivalent to 4 "channels" as far as the AMD is concerned, has a data transfer rate full duplex "both ways" of 9,900 bits per second. LSCs and SC1s seize this amount of bandwidth automatically. This occurs the instant the card is plugged in. It makes no difference whether or not data is being transferred.

All bandwidth left over after the LSCs and SC1s are plugged in is allocated dynamically to the High Speed Devices.

Provided that the total BUS capacity does not exceed 1050, then no problems should be encountered in normal operation. If this value is exceeded, contention starts to occur. The effect of this will be a "slow down" High Speed Devices. This tends to lower the throughput of all High Speed Devices. The LSCs and SC1s are not affected since they are polled by the buffer and always have their turn on the BUS.

(NOTE : For more information on calculating BUS LOADS, see Cray Communications Publication 918-5238, Issue 7, Appendix B).

DCX 844 PRODUCT

The DCX 844 does not have through put calculations due to the unit being an ARQ concentrator and distributor for other DCX ARQ products.

The only delay from this product is a 200 microsecond for reformatting the data from the ARQ links.

DCX 808 and DCX 832

The DCX 808 and DCX 832 has a through put calculations as follow :
(Note : These number are based on an end-to-end data transfer calculation.)

At 9600bps the through put is 8970bps with a 40 to 50 msec. delay.
At 19200bps the through put is 9265bps with a 40 to 50 msec delay.

APPENDIX B

STDM INSTALLATION AND CUTOVER TESTS AT ZMP AND REMOTE SITES

| STDIM INSTALLATION and CUTOVER TESTS at ZMP | | | | | |
|---|--------------|----------------------|--|-------------------|-----------|
| STDIM | INSTALLATION | CUTOVER | INTERFACE | LOCATION | SITE |
| 840/850 | | 6-16-93 As Listed | ZMP Remotes | Farmington, MN | ZMP-ARTCC |
| | | 6-17-93 | CBI-Viking | | |
| | | 6-17-93 | CBI-PC | | |
| | | 6-17-93 | MMS | | |
| | | 6-17-93 | Apollo | | |
| 816 | | 6-17-93 | MMS-T | Fargo, ND | FAR-AFSFO |
| 816 | | 6-17-93 | MMS-T | Sioux Falls, SD | FSD-ATCT |
| 816 | | 6-17-93 | MMS-T | Bismark, ND | BIS-ATCT |
| 808 | | 6-17-93 | MMS-T | Rochester, MN | RST-ATCT |
| 808 | | N/A | NO LINE | Hibbing, MN | HIB-AFSFO |
| 832 | | 6-17-93 | MMS-T CBI-Viking CBI-PC | Bismarck, ND | BIS-GNAS |
| 808 | | 6-17-93 | MMS-T | Tyler, MN | QJC-ARSR |
| 808 | | 6-17-93 | MMS-T CBI-Viking | Nashwauk, MN | QJD-ARSR |
| 808 | | 6-17-93 | MMS-T | Gettysburg, SD | QJB-ARSR |
| 808 | | 6-17-93 | MMS-T | Grand Forks, ND | GFK-ATCT |
| 808 | | 6-17-93 | MMS-T | Duluth, MN | DLH-ATCT |
| 808/844 | | 6-28-93 | MMS-T MMS-P CBI-Viking | Minneapolis, MN | MSP-ATCT |
| 808 | | 6-18-93 | MMS-T MMS-P CBI | Finley, ND | QFI-ARSR |
| 832 | | 6-18-93 | MMS-T MMS-P CBI-Viking CBI-PC | Minneapolis, MN | MIN-GNAS |
| 808 | | 6-18-93 | MMS-T | Alexander, ND | QWA-ARSR |

APPENDIX C

**NAS-SS-1000 REQUIREMENTS FOR STATISTICAL MULTIPLEXERS
(TYPES I, II, AND III)**

DMN Phase IIIA STATISTICAL MULTIPLEXER TYPE I NAS SS-1000 Vol-I VRTM

September 1993

| REQ | NAS SS-1000 Volume I Paragraph | FAA-E-2860 Paragraph | NAS SS-1000 Volume I Requirement | Verification Level/Method | | TEST RESULTS | | |
|-----|--------------------------------------|-------------------------|-------------------------------------|------------------------------|------|--------------|-------------|-------------|
| | | | | Unit | Int. | OCD ABQ | FAA T.C. | Key Site |
| | | | | | | | | |

There are no NAS SS-1000 Volume I requirements for the DMN Type-I Statistical Multiplexer.

VERIFICATION METHODS: A=Analysis D=Demonstration I=Inspection T=Test X=Not Applicable

NOTES:

DMN Phase IIIA STATISTICAL MULTIPLEXER TYPE II NAS SS-1000 Vol-I VRTM

September 1993

| REQ | NAS SS-1000 Volume I Paragraph | FAA-E-2860 Paragraph | NAS SS-1000 Volume I Requirement | Verification Level/Method | | TEST RESULTS | | | Note |
|-----|--------------------------------------|-------------------------|-------------------------------------|------------------------------|------|--------------|-----|-------------|------|
| | | | | Unit | Int. | OCD | ABQ | FAA T.C. | |
| | | | | | | | | | |

There are no NAS SS-1000 Volume 1 requirements for the DMN Type-II Statistical Multiplexer.

VERIFICATION METHODS: A=Analysis D=Demonstration I=Inspection T=Test X=Not Applicable

NOTES:

DMN Phase IIIA STATISTICAL MULTIPLEXER TYPE III NAS SS-1000 Vol-I VRTM September 1993

| REQ | NAS SS-1000 Volume I Paragraph | FAA-E-2860 Paragraph | NAS SS-1000 Volume I Requirement | Verification Level/Method | | TEST RESULTS | | | Note |
|-------|--------------------------------------|-------------------------|---|------------------------------|------|--------------|-----|------|------|
| | | | | Unit | Int. | OCD | FAA | T.C. | |
| Title | 3.2.1.1.8.1.1 | | DATA COMMUNICATIONS | | | | | | |
| 375 | 3.2.1.1.8.1.1.b | 3.1.1.4.3.a | Flexibility to enable reconfiguration of facility and/or subsystems connectivity for backup communications capabilities when system failures occur; | D | D | Pass | | | |
| Title | 3.2.1.1.9.1 | | REMOTE MAINTENANCE MONITORING FUNCTIONAL CHARACTERISTICS | | | | | | |
| 376 | 3.2.1.1.9.1.a | 3.1.1.4.5.1 | The NAS shall continually monitor subsystem performance to obtain the data needed by specialists for maintenance and operations support; | D | D | Pass | | | |
| 377 | 3.2.1.1.9.1.b | 3.1.1.4.5.4 | The NAS shall provide the status of subsystems to specialists and shall generate an alarm upon the deviation of designated parameters from prescribed limits; | D | D | N/A | 26 | | |

| | | | | | |
|-----------------------|------------|---|--------------|--------|------------------|
| VERIFICATION METHODS: | A=Analysis | D=Demonstration | I=Inspection | T=Test | X=Not Applicable |
| NOTES | NOTE-26 | Not applicable to this COTS (STDM) equipment. | | | |

DMN Phase IIIA STATISTICAL MULTIPLEXER TYPE III NAS SS-1000 Vol-I VRTM September 1993

| REQ | NAS SS-1000 Volume I Paragraph | FAA-E-2860 Paragraph | NAS SS-1000 Volume I Requirement | Verification Level/Method | | TEST RESULTS | | | Note |
|-----|--------------------------------|----------------------|--|---------------------------|------|--------------|------|------|------------|
| | | | | Unit | Int. | OCD | ABQ | FAA | |
| 378 | 3.2.1.1.9.1.c | 3.1.1.4.3.b | The NAS shall provide the capability for a specialist on-site or at an off-site location to control selected subsystems for maintenance purposes: | | D | D | | Pass | |
| 379 | 3.2.1.1.9.1.d | 3.1.1.4.5.4 | The NAS shall provide the specialist the capability to identify the line replaceable unit causing an equipment failure: | | D | D | | | Shake down |
| 380 | 3.2.1.1.9.1.g | 3.1.1.4.5.4 | The NAS shall provide the specialist access to the monitoring, control, and data management capabilities of the NAS as required and as authorized by administrative directive: | | D | D | Pass | | |

| | |
|-------|---|
| NOTES | VERIFICATION METHODS: A=Analysis D=Demonstration I=Inspection T=Test X=Not Applicable |
|-------|---|

DMN Phase IIIA STATISTICAL MULTIPLEXER TYPE I NAS SS-1000 Vol-IV VRTM

September 1993

| REQ | NAS SS-1000 Volume IV Paragraph | FAA-E-2860 Paragraph | NAS SS-1000 Volume IV Requirement | Verification Level/Method | | TEST RESULTS | | | Note |
|-----|---------------------------------------|-------------------------|--|------------------------------|------|--------------|-----|------|------|
| | | | | Unit | Int. | OCD | ABQ | FAA | |
| 381 | 3.2.1.4.1.1.2.2.1 | 3.1.1.1.1 3.1.1.1.2 | MULTIPLEXER TYPES The transmission equipment shall provide the following types of multiplexers: b. Statistical multiplexers | | | T | T | Pass | |
| 382 | 3.2.1.4.1.2.6.2.2 | 3.1.1.1.2.2.b | INPUT DATA RATES The statistical multiplexers shall accommodate input data rates from 50 to 9600 bps. | | | T | T | Pass | 28 |

VERIFICATION METHODS: A=Analysis D=Demonstration I=Inspection T=Test X=Not Applicable

NOTES Note-28 Type I STDM can accommodate input data rates from 50 to 19,200 bps

DMN Phase IIIA STATISTICAL MULTIPLEXER TYPE II NAS SS-1000 Vol-IV VRTM

September 1993

| REQ | NAS SS-1000 Volume IV Paragraph | FAA-E-2860 Paragraph | NAS SS-1000 Volume IV Requirement | Verification Level/Method | | TEST RESULTS | | | Note |
|-----|---------------------------------------|-------------------------|--|------------------------------|------|--------------|-------------|-------------|------|
| | | | | Unit | Int. | OCD | FAA T.C. | Key Site | |
| 383 | 3.2.1.4.1.1.2.2.1 | 3.1.1.1.1 3.1.1.1.2 | MULTIPLEXER TYPES The transmission equipment shall provide the following types of multiplexers: b. Statistical multiplexers | | T | T | Pass | | |
| 384 | 3.2.1.4.1.2.6.2.2 | 3.1.1.1.2.2.b | INPUT DATA RATES The statistical multiplexers shall accommodate input data rates from 50 to 9600 bps. | | T | T | Pass | | 29 |

VERIFICATION METHODS: A=Analysis D=Demonstration I=Inspection T=Test X=Not Applicable

NOTES Note-29 Type II STDM can accommodate input data rates from 50 to 19,200 bps

DMN Phase IIIA STATISTICAL MULTIPLEXER TYPE III NAS SS-1000 Vol-IV VRTM
September 1993

| REQ | NAS SS-1000 Volume IV Paragraph | FAA-E-2860 Paragraph | NAS SS-1000 Volume IV Requirement | Verification Level/Method | | TEST RESULTS | | | |
|-----|---------------------------------------|-------------------------|---|------------------------------|------|--------------|-----|-------------|-------------|
| | | | | Unit | Int. | OCD | ABQ | FAA T.C. | Key Site |
| 385 | 3.2.1.4.1.2.2.1 | 3.1.1.1.1 3.1.1.1.2 | MULTIPLEXER TYPES The transmission equipment shall provide the following types of multiplexers: b. Statistical multiplexers | T | T | | | Pass | |
| 386 | 3.2.1.4.1.3.1 | 3.1.1.4.5.1 | PERFORMANCE MONITORING and ALARM GENERATION The transmission equipment shall collect data on its own performance and generate alarms when critical performance parameters are out of tolerance. | D | D | N/A | | 30 | |
| 387 | 3.2.1.4.1.3.1.2 | 3.1.1.4.5.1 | DATA MULTIPLEXER AUTOMATED NETWORK MANAGEMENT SYSTEM (ANMS) The data multiplexer ANMS shall collect data on the performance of data multiplexers and transmission media and generate alarms when performance parameters are out of tolerance. | D | D | N/A | | 30 | |

VERIFICATION METHODS: A=Analysis D=Demonstration I=Inspection T=Test X=Not Applicable

NOTES Note-30 Not applicable to this COTS (STDIM) equipment

DMN Phase IIIA STATISTICAL MULTIPLEXER TYPE III NAS SS-1000 Vol-IV VRTM

September 1993

| REQ | NAS SS-1000 Volume IV Paragraph | FAA-E-2860 Paragraph | NAS SS-1000 Volume IV Requirement | Verification Level/Method | | TEST RESULTS | | Note |
|-----|---------------------------------------|-------------------------|---|------------------------------|------|--------------|-------------|------|
| | | | | Unit | Int. | OCD ABQ | FAA T.C. | |
| 388 | 3.2.1.4.1.1.4 | 3.1.1.4.5.6 | TRANSMISSION EQUIPMENT FAULT ISOLATION The transmission equipment shall provide test equipment necessary to isolate transmission equipment faults. | T | T | Pass | | |
| 389 | 3.2.1.4.1.2.6.2.1 | 3.1.1.4.1 | INPUT PORTS The statistical multiplexers shall accommodate up to 240 asynchronous or 120 synchronous input ports. | A | A | Pass | | |
| 390 | 3.2.1.4.1.2.6.2.2 | 3.1.1.1.2.2.b | INPUT DATA RATES The statistical multiplexers shall accommodate input data rates from 50 to 9600 bps. | T | T | Pass | | 31 |
| 391 | 3.2.1.4.1.2.6.2.3 | 3.1.1.4.2.a | COMPOSITE LINK PORTS The statistical multiplexers shall accommodate up to 14 synchronous composite links. | A | A | Pass | | |
| 392 | 3.2.1.4.1.2.6.2.4 | 3.1.1.4.2.b | COMPOSITE LINK DATA RATES The statistical multiplexers shall accommodate composite link data rates up to 56 kbps. | T | T | Pass | | |

VERIFICATION METHODS : A=Analysis D=Demonstration I=Inspection T=Test X=Not Applicable

NOTES Note-31 Type III STDM can accomodate input data rates from 50 to 19,200 bps.